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A novel hybrid MCDM approach for complicated supply chain management problems in construction

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Abstract

The paper tackles a hybrid multi-criteria decision-making (MCDM) model related to supply chain management, problems, and the supplier selection problem. Modern management of materials and products requires continuous evaluation of numerous complex social, ecological, and economic factors. A group decision process using Analytic Hierarchical Process (AHP) approach presented to find the criteria weights. Measurement of conflict among criteria and decision makers presented with illustration and numerical example. Firstly, eight evaluation criteria, including cost, quality, distance, and delivery, reliability, reputation, and technology level, compatibility, and development ability identified. Later, the ARAS and the Multiplicative Utility function adopted for ranking and selecting suppliers. Criteria values normalized according to Hovanov method. The ARAS method with this normalisation method named as a hybrid original model INMUARAS.

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Keywords: AHP; ARAS; Multiplicative utility function; hybrid model; INMUARAS; selection; construction; supply chain.

1. Introduction

The past few decades have seen increased concern for environmental issues by companies, governments, and the public. Since the 3Rs of Reduce, Recycle and Remanufacture are the basic requirement for green supply chain activities, a closed loop management from in-plant production to off-plant forward and reverse logistics has to be

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taken care of so that environmental impact and energy usage can be minimized.

Due to global intensive competition, many companies prioritize quick and precise responses to customers' various demands improving their supply chain management. Many strategic issues that confront business today stem from the new rules of competition, globalization down pressure on price and the customer taking control. However, such activities not generate savings or revenues, and thus are non-understandably for companies as cost centres.

Examples of strategies used to achieve the aims include:

- Use of environment-friendly materials;
- Product or process modifications to improve efficiency and reduce attendant environmental releases;
- Optimal operation of processes to minimize consumption of energy or raw materials and generation of waste, and
- Implementing exchange of waste streams between process and plants to achieve industrial symbiosis.

Thus, decisions on supplier selection are as one of the most important aspects of production planning and control. The term of supply chain management firstly used in the 1980s. A supply chain includes all activities, functions, and facilities in the flow and transformation of goods and services from the material stage to the end user. The objective of supply chain management is to maximise value in the supply chain. In addition, selecting suitable suppliers significantly reduces material purchasing cost, improves the competitiveness of businesses, increases flexibility and product quality, and helps with speeding up the process of material purchasing.

Experience from management of any complex system points toward some guidelines for the selection of strategic paths:

- Once basic principles for the ultimate goal are clear, the individual's potential for dealing with trade-offs and for optimizing chances in multidimensional and complex situations (e.g., medical treatment) grows with experience.
- The complete investment path need not necessarily be determined up-front, only smart flexible steps followed by continuous reassessment as the "game" unfolds.
- Beyond a certain level of specificity, checklists may confuse more than help decision makers.

Supply chains comprise potential suppliers, producers, distributors, retailers, customers, etc. (Fig. 1). The repetitive nature of supplier selection process and frequently changing customer demands lead to the increase in the uncertainty and ambiguity of this decision-making process. Therefore, in order to achieve the successful operation of an ASC, an effective supply partner selection becomes an essential process that may enhance effectiveness, efficiency, quality, safety and profit. Supplier selection defined as a process for identification of an efficient combination of suppliers, producers and distributors, depending on which the right mix and quantity of products and services provided to customers.

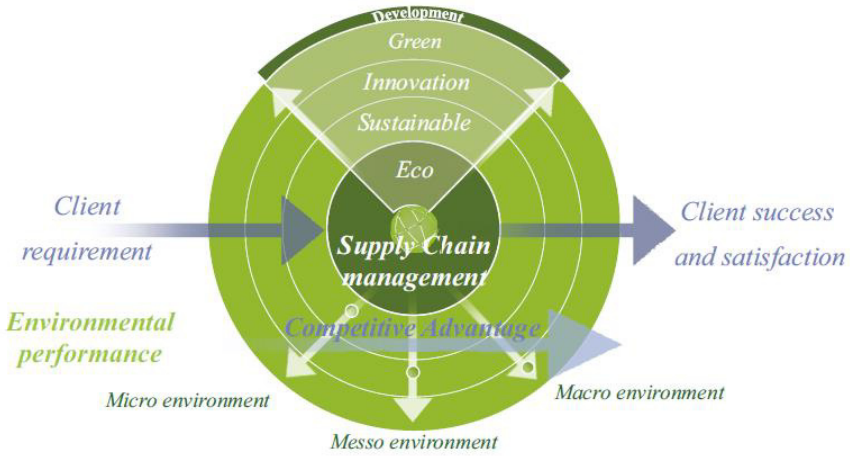

Fig. 1. Supply chain management.

Supplier selection is a multiple criteria decision-making (MCDM) problem affected by several conflicting factors. The high value of a problem-solving process is that it helps to align human's thinking and action around a common approach for winning team problem solving to the following nine steps:

1) Selecting the problem;
2) Exploring the problem and gathering data;
3) Establishing success attributes;
4) Developing a clear problem statement;
5) Generating alternatives;
6) Evaluating alternatives;
7) Selecting a preferred solution;
8) Developing a plan for action;
9) Testing and modifying the solution.

Consequently, a purchasing manager must analyse trade-off between several criteria. MCDM techniques support decision-makers in evaluating a set of alternatives.

2. Supplier selection model in complex environment

The study has summarized the latest studies on supplier selection and pointed out eight evaluation criteria: cost, quality, distance, delivery reliability, reputation, technology level, compatibility and development ability (Fig. 2).

To solve the supplier selection problem was developed original model, which based on three different methods namely: AHP, ARAS, and Multiplicative Utility function. In this case is applied normalization method according to Hovanov [1].

$$\dddot{x}_{ij} = \left(\frac{\left(x_{ij} - \min_i x_{ij} \right)}{\left(\min_i x_{ij} - \min_i x_{ij} \right)} \right)^2 \tag{1}$$

$$\dddot{x}_{ij} = \left(\frac{\left(\max_i x_{ij} - x_{ij} \right)}{\left(\min_i x_{ij} - \min_i x_{ij} \right)} \right)^2$$

The integrated hybrid utility function value of the proposed approach for an alternative could be determined as follows:

$$K_i = \lambda \sum_{j=1}^{n} Q_i + (1-\lambda) \sum_{j=1}^{n} P_i \; ; \; \lambda = 0, \ldots, 1, 0 \le K_i \le 1. \quad (2)$$

λ is determined based on the assumption that total of all alternatives ARAS scores must be equal to the total of MUF scores:

$$\boldsymbol{\lambda} = \frac{\sum_{i=1}^{m} P_i}{\sum_{i=1}^{m} Q_i + \sum_{i=1}^{m} P_i}. \quad (3)$$

Final step: Rank preference order. The best alternative is one with the maximal K_i value.

The problem of supporting supplier selection have been analysed by a number of authors. In addition, there are numerous evaluation methods for selecting the required suppliers. Numerous researches concentrate on the problem of selecting supplier using different methods. The pairwise comparison matrix usually consists of elements expressed on a numerical scale to quantify the qualitative decision problem. Therefore, the first issue for a pairwise comparison matrix is that how to develop a scale to transfer the linguistic description to the numerical values, including 9-point Ratio Scale introduced by Saaty [2], Differences Scale proposed by Triantaphyllou and Mann [3] and the Exponential Scales developed by Lootsma [4,5] etc.

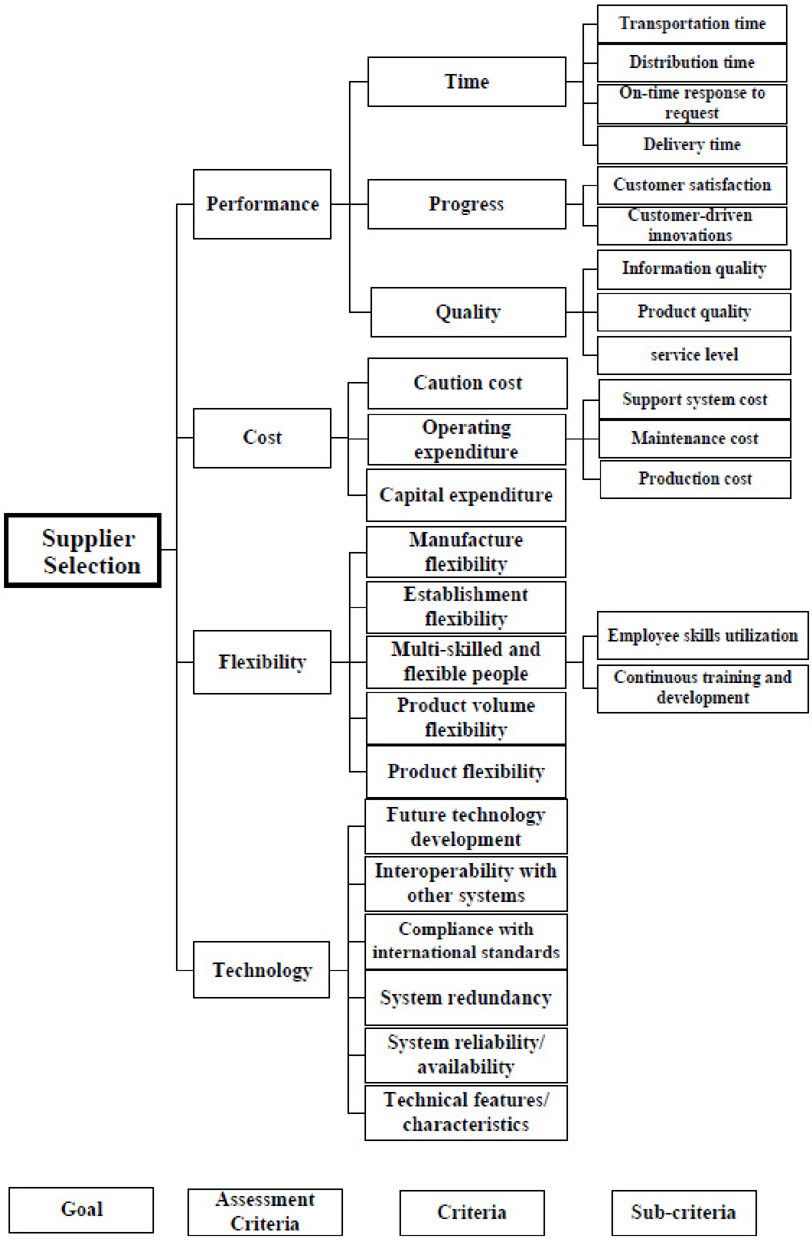

Fig. 2. Hybrid supplier selection model [6].

The values of elements in an initial decision-making matrix given by decision makers based on their experiences and expertise.

However, in reality, decision makers are often facing complicated decision problems that are not structuring hierarchically. Furthermore, the interactions of decision attributes within the same level and the feedbacks between two different levels are important issues that should be considered during the decision making process. Therefore, the AHP method does not work accurately when solving such decision problems [7].

Once a set of pairwise comparison matrices constructed for a problem, the priority weights of alternatives derived from these matrices, and then a decision made in terms of the ranking order of the alternatives. Nowadays exists more than 20 different methods that can be used to derive the weights of criteria [8, 9, 10], including the Normalization of the Column Sum Method and Arithmetic Mean of Normalized Columns Method, the Eigenvector Method [11], and the Direct Least Squares Method, the Weighted Least Squares Method [12], the Logarithmic Least Squares Method [13], and Geometric Means Solution [14], the Logarithmic Goal Programming Method [15], and etc. The AHP method is the most popular among these methods.

The typical steps of AHP include the following five steps:

1) Define the problem and decompose the problem;
2) Construct a set of pairwise comparison matrices;
3) Calculate eigenvalues and eigenvectors by Eigenvector Method;
4) Test the consistency of all comparison matrices;
5) Aggregate the final priorities of alternatives to make decision.

Saaty proposed AHP as a multiple criteria decision-making method applied to overcoming problems under uncertain conditions. It was used to solve different problems [16,17,18].The goal of different MCDM methods is finding the rational solution.

There proposed hybrid MCDM model to pursue the decision-maker find the rational solution. Hierarchy appraisal and decomposition of the problem separation makes it possible to describe the problem. The goal of the proposed model achieve a more accurate solution.

The ratio scale (intensity) and definition of AHP [19] given bellow:

1 – Equal importance;
3 – Somewhat more important;
5 – Much more important;
7 – Very much more important;
9 – Absolutely more important;
2, 4, 6, and 8 – Intermediate values.

3. A case study: selecting a supplier company

Nature of the construction work is a specifically complex array of interdependent activities, i.e. it is at best organized chaos. Construction is a sector that accepts innovations slowly. Selection of effective technological systems in construction is a complex multi-criteria task [20]. Clients are slow with communication. The main challenges of construction works to managers [21,22] are as follows: changing market demand, customers' request, and technological advances, the work highly affected by weather and other environmental conditions [23,24,25], not exists the same way to manage every project [26]. Multi-criteria analysis is a useful tool in many similar problems [27,28,29,30]. By proactively addressing alternatives of supply management problems correctly, the project should cost less, be completed more quickly and produce products more likely to meet the client's requirements [31].

The aim of this case study is to utilize a new hybrid model of MCDM methods for selecting a supplier.

3.1. Selecting criteria and survey data

Construction Company tends to select one supplier among three partners.

A group of 10 senior experts, the majority of which have been working in the companies producing disposable containers for at least six years, formed to solve the problem. 50 % of the respondents are BA graduates and 100 % of those have industrial background. At the first stage was applied nominal group Delphi technique to determine the main criteria for supplier assessment.

Eight evaluation criteria to select the best supplier used as follows (optimisation direction):
x_1 – cost (minimum);

x_2 – quality (maximum);
x_3 – distance (minimum);
x_4 – delivery reliability (maximum);
x_5 – reputation (maximum);
x_6 – technology level (maximum);
x_7 – compatibility (maximum);
x_8 – development ability (maximum).

3.2. Supplier selection

After summarising the opinions of senior experts and the steps of AHP, the weights of evaluation criteria provided in Table 1. The initial decision-making matrix X normalised and weighted initially and the obtained result (X) provided in Table 2. ARAS method, originally presented by Zavadskas and Turskis [32], mainly used to solve multi-criteria problems in construction [33,34,35]. In accordance the ARAS method and Multiplicative Utility function, the evaluation of four suppliers computed and ranking suppliers for Construction Company is finally discovered (Table 2, and 3).

Table 1. The initial decision-making matrix and the values of evaluation criteria.

	x_8	x_4	x_2	x_1	x_3	x_5	x_6	x_7
w	0.207	0.197	0.14	0.122	0.147	0.1	0.047	0.04
Opt	max	max	max	min	min	max	max	max
A_1	36	32	49	23	12	37	39	36
A_2	31	37	42	25	26	45	38	39
A_3	41	33	44	19	32	40	42	42
A_4	30	37	42	27	45	39	45	39
Optimal	50	50	50	15.9	10	50	50	50
Worst level	30.000	30.000	30.000	27.000	45.000	30.000	30.000	30.000

Table 2. Normalised matrix.

	x_8	x_4	x_2	x_1	x_3	x_5	x_6	x_7	MUF	Rank
w	0.207	0.197	0.14	0.122	0.147	0.1	0.047	0.04	P_i	4
Opt	max	max	max	min	min	max	max	max		
A_1	0.490	0.810	0.003	0.409	0.003	0.423	0.303	0.490	0.130	
A_2	0.903	0.423	0.160	0.672	0.209	0.063	0.360	0.303	0.296	2
A_3	0.203	0.723	0.090	0.078	0.395	0.250	0.160	0.160	0.200	3
A_4	1.000	0.423	0.160	1.000	1.000	0.303	0.063	0.303	0.374	1
A_0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0

Table 3. Weighted normalised matrix.

	x_8	x_4	x_2	x_1	x_3	x_5	x_6	x_7	ARAS	Q_i	Rank
A_1	0.101	0.160	0.000	0.050	0.000	0.042	0.014	0.020	0.388	0.388	3
A_2	0.187	0.083	0.022	0.082	0.031	0.006	0.017	0.012	0.440	0.440	2
A_3	0.042	0.142	0.013	0.010	0.058	0.025	0.008	0.006	0.303	0.303	4
A_4	0.207	0.083	0.022	0.122	0.147	0.030	0.003	0.012	0.627	0.627	1
A_0	0.207	0.197	0.140	0.122	0.147	0.100	0.047	0.040	1.000	1.000	0

4. Conclusion

Presented methodology allows solving supply chain management problems taking into account the inherent interconnectivity of the processes that comprise them. It thus yields valuable insights on how such improve technology or network configuration. There has thus been corresponding improvement in the reliability, consistency, and ease to interpretation findings of supply chain management. The future should see more multi-criteria decision-making support methods in supply chain applications, as well as methodological advances, including life cycle based optimization models, dynamic supply chain management, sustainable supply chain management, and software implementations of these new computing approaches.

In conclusion, it is possible that the relatively high impact of supply chain management on business decisions is not only related to relatively low use of the method by decision makers in business, but also to relatively low relevance of traditional supply chain management for such purposes.

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